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NEREOCYSTIS AND PELAGOPHYCUS

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Nereocystis Luetkeana (Mert.) P. & R. is one of the most striking of all the algae of the western coast of North America, yet very varied statements are made concerning its dimensions and duration. This matter has been brought up again recently by Professor T. C. FRYE, who in an article in this journal (42:143-146. 1906) states certain facts and suggestions from his observations on this species as it occurs in Puget Sound.

In the first place, FRYE doubts that this species ever reaches a length of over 21^m, although in no case does he mention that he has made any measurements, and he regards a length of 90^m as beyond the bounds of credibility. It is to be regretted that so few authentic measurements are on record for plants of this species, especially for those of the greater lengths. It is difficult, however, to obtain reasonably perfect plants out of the water and in such a position that they may be measured with accuracy. The statement of 90^m rests, so far as I know, upon that made by MERTENS (Linnaea 4:48. 1829) that the stipes reach a length of 45 *Faden* or fathoms, making in all something approaching 90^m, and that the Aleuts use them for fish-lines, one of which he himself bought. It seems likely that MERTENS' statement about the length of these lines must have been made with care, as are his statements in general. Of course it may be that there is a misprint here for 15, which, from all experience, seems likely. RUPRECHT, however, says (Neue oder unbek. Pfl. a. d. nördl. Th. des stillen Oceans, p. 22. 1852) that *Nereocystis*, in the neighborhood of Bodega, California, reaches a length of 25 English feet, but that according to trustworthy natives in the employ of the N. A. Company at Fort Ross, it reaches a length ten times greater in the neighborhood of Sitka and the Aleutian Islands. This would correspond with MERTENS' figures. This impressed RUPRECHT to such an extent that he suggested (*l. c.* 22) that the southern smaller plant might belong to a different species. I have had an opportunity of observing this species at different localities of its growth from Kadiak Island on

the coasts of the Alaskan Peninsula down to Port Harford in California. I have never seen any specimens which approximated to the dimensions mentioned by MERTENS and RUPRECHT. All along the west coast, however, it grows out into water having a depth of 12 to 15 fathoms, and this, which is about 30^m, represents the length of the solid portion of the stipe of the adult plant. The hollow portion, both apophysis and bulb, commonly floats on the surface, as do also the long leaves. Off the entrance to Yakutat Bay, Alaska, while at anchor during a fog, I saw soundings taken close to and among *Nereocystis* plants, showing that the solid portions of the stipes were 10 to 12 fathoms in length. Altogether the plants thus observed must have been in the neighborhood of 45 to 50^m total length, or nearly, if not quite, twice as long as the maximum credited by FRYE. On the coasts of California, I have measured many specimens cast ashore. The longest specimen, in reasonably perfect condition, I ever found cast ashore was on the beach at Carmel Bay in Monterey County, California. Not having a tape line, I resorted to pacing. Its greatest length was 41 good paces, which by measurement of my average pace fully equals that number of meters. All these figures from my own experience come from plants growing in the open. From these and from the experience of the great length attained by the various plants growing in swift currents, I am not prepared to reject the greater lengths recorded by MERTENS and RUPRECHT.

FRYE makes some point of the rock attachment of *Nereocystis Luetkeana* and it certainly is commonly attached to the rocks or to stones. On the Californian coasts, however, I often find it anchored firmly by its holdfasts to other members of the Laminariaceae, particularly to *Pterygophora californica*. I have seen stipes of *Pterygophora* to which as many as five or six holdfasts of *Nereocystis* were attached.

The origin of the numerous blades of *Nereocystis Luetkeana* has been made plain through the investigations of a number of writers. At first there is a single blade when the plant is in the primitive laminarioid condition. Soon, and at about the time that the bulb is beginning to form, this splits into two, which by the expansion of the bulb are separated considerably at the base. These in turn split again and are also in the same way separated at the base. The first two or three

splittings, thus taking place when the bulb is rapidly expanding, become widely separated and form four to six centers for further splitting and growth. This is well shown in the fine plates of POSTELS and RUPRECHT (Ill. Alg. *pls.* 8, 9. 1840), in that of SAUNDERS (Algae of the Harriman Expedition. *pls.* 58, *fig.* 1, and 59, *fig.* 8. 1898), and less accurately in that of MACMILLAN (Bull. Torr. Bot. Club **26**: *pl.* 361. *fig.* 5. 1899). The normal certainly seems to be four centers thus separated and which then proceed to form blades by further splittings, but without any considerable separation. I have also described this process in my paper "The elk-kelp" (Erythea **4**: 183. 1896). The type of division in this case is a regular dichotomy but, as happens just as considerably in *Lessonia*, the absolute regularity is interrupted in minor details. However, *Nereocystis Luetkeana* has the regularity of its dichotomy as complete as do the species of *Lessonia*, and has no such scorpioid unilaterality in its branching and in the succession of divisions leading up to it as does its near relative *Macrocystis*. Between the two, but nearer, as it seems to me, to *Macrocystis* in this respect is *Pelagophycus*. SKOTTSBERG (Zur Kenntn. d. Subantarkt. u. Antarkt. Meeresalgen **1**: 137, 138. 1907) seems to take the opposite view and to consider that after the first splitting in *Nereocystis Luetkeana*, the other splittings are unequal as in *Macrocystis*. An investigation of a large number of older and younger individuals convinces me that such is not the case. In *Postelsia* also the splitting is largely equal, but finally there comes something of unilateral splitting, so that while *Postelsia* really stands next to *Lessonia* and *Nereocystis*, it approaches slightly also *Pelagophycus*. This point will be returned to below.

Since the time of MERTENS, it has been generally received and all evidence has seemed to show that *Nereocystis Luetkeana*, in spite of its large size, is an annual plant. In his paper FRYE has distinctly discredited that belief, and while he does not say so in so many words, he intimates very strongly that it is a biennial plant. He says (*l. c.* 143): "Fishermen and pilots . . . say that it disappears in winter," and later (p. 143) he says: "The fishermen are partly right. Except for stragglers here and there, the kelps are gone; while those remaining were nearly all decayed and loose, with their fronds mostly torn away." This observation was made in March to supplement obser-

vations made the previous June. Also in March, however, he finds plants 3 to 9^m below the surface which have reached a length of 1.25 to 2.5^m, in consequence of which he makes the significant statement that "it seems that they do not reach the surface the first year but remain out of reach of waves, pushing up rapidly in the second season only to die when winter overtakes them." He does not tell us what period of time is included in what he calls the first season, but he does call the second season also the second year. It is proper to assume, then, as it seems to me, that he believes that in the first year, spring and summer probably, the growth is slow and only plants up to 2.5^m or thereabouts are produced, while in the second year the rest of the growth of 18 to 20^m is produced. Growth during the winter season also must be, according to his idea, very slow or stopped altogether. This assumption seems necessary in order to arrive at the conclusion that the growth of 1.25 to 2.5^m had been accomplished in the previous year instead of a few previous months. Yet it does not seem that the assumption is justified by known facts, since evidently the date of the germination and season of the sporeling stages have not been observed. That the plants of colder waters, especially Phaeophyceae, can carry through their entire life-processes at a temperature which never rises above the freezing-point has been demonstrated by KJELLMAN (*Algae of the Arctic Sea*, p. 31. 1883), since he says: "At that depth where the richest marine vegetation is to be found, it [the temperature] does not rise in general above 0° C. at any time of the year." From what we know of the temperature of the surface waters of the region of Puget Sound, it seems safe to infer that the temperature of the waters within a few fathoms of the surface cannot be lower than somewhere between 5° and 10° C. at any time of the year. Furthermore, one cannot judge of the temperature of the water by the temperature of the air, and especially of the water 3 to 9^m below the surface. Consequently, even if the surface of the ground were frozen (cf. FRYE, *l. c.* 144) it is not necessarily true that the water at the depths stated might have been anywhere near the freezing-point. Farther, KJELLMAN adds (*l. c.* 31 ff.) that the temperature of the air affects only the algae of the littoral zone, for it is only those algae which are exposed to the air. Finally, it seems to me, after considering all the facts upon which FRYE's con-

clusion is based, at least so far as they are presented, that it is not necessary to assume that the initial growth of 2 or 3^m must have taken place in the previous year, especially when it is clear that a growth of 18^m can occur in two months and a half, viz., from the middle of March to the first of June. There certainly seem to be no theoretical impossibilities in the way of its having all taken place in the same year.

Nereocystis Luetkeana is fairly abundant on that portion of the coast of California lying to the north of Point Conception and I have followed its growth with some care. My conclusions are different from those of FRYE. Many plants arise in pools and in the deeper tideways among the reefs, and some persist through to the fruiting stage. Such plants are easy of observation and the results may be checked by more limited observation of the plants of the deeper waters. I find that they appear in February and March, for the most part, and in places where none are to be seen in December or January, and that they pass through their different stages of growth and fruiting by November, and for the most part disappear in December or January of the same year. The young plants with and without bulbs are in greatest abundance in March, although in some years they are present early in February, and this occurs in the same locality year after year. Belated specimens appear later, but as stragglers, the general rule being as stated above. It has been possible, therefore, to follow the same group of individuals through their life-history, and the result shows that the period of active existence is about nine or ten months and within the period of one year. Exceptional times of germination may occur and I find some, but in such cases the plants are usually tide-pool plants and do not develop beyond a certain stage. MACMILLAN mentions (*l. c.* 274) a set of sporelings of 0.5^{mm} and upward in size, in two feet of water in June, off San Juan Island, Washington. I have never found any young plants so late in the year, but I have found adult fruiting plants as late as April and in prime condition, but they are decidedly out of season, and the cases can be paralleled among annual flowering plants, so that they do not really affect the general truth of the statement as to the annual character of these plants.

The floating seaweeds of the group of the Phaeophyceae have long

attracted attention, especially from the early navigators, and while attention in the Atlantic Ocean has been directed particularly to the species of Sargassum or gulfweed, in the Pacific several of the larger members of both Fucaceae and Laminariaceae were early used as indications of the approach toward land. Of all of these, perhaps no one was of such usefulness in this connection as the so-called *Porra* of the Spanish navigators approaching the coast of Lower California on their voyages from the Philippine Islands. RUPRECHT (*l. c.* 22-24) has given a fairly full discussion of this and other names applied by the Spaniards to these floating algae, but he did not have access to all the books, nor is the case different with myself. I have one point, however, to add to the account of RUPRECHT, which I think will clear up the more important part of the subject.

One of the earlier references is that of ANSON, whose voyage round the world in the years 1740 to 1744 was written from his papers and other materials by RICHARD WALTER, chaplain of one of the ships of the expedition, and passed through many editions. On p. 335 of the fourth abridged edition (London, 1748), and in the same language in the larger or so-called Admiralty editions (p. 243 in 1st, 1748; same page in 12th, 1767, and in 15th, 1776), occurs the following, regarding the "Manila ship":

. . . and when she has run into the longitude of 96° from Cape Espiritu Santo, she generally meets with a plant floating on the sea, which being called "*Porra*" by the Spaniards, is, I presume, a species of sea-leek. On the sight of this plant they esteem themselves sufficiently near the Californian shore, and immediately stand to the southward; and so much do they rely on this circumstance that on the first discovery of the plant the whole ship's company chaunt a solemn *Te Deum*, esteeming the difficulties and hazards of their passage to be now at an end; and they constantly correct their longitude thereby, without ever coming within sight of land.

ANSON's account gives us no further details concerning the nature of the plant. LEGENTIL, however, goes more into detail in his *Voyage dans les mers de l'Inde*, published at Paris in 1781. The expedition was made in the years 1768 and 1769, to observe the transit of Venus, and made many observations of a scientific nature in other lines than astronomy. On p. 215, he quotes ANSON in regard to *Porra*, translating into French the passage quoted above. LEGENTIL, however, goes on to give a figure of the *Porra* (cf. Vol. II, *pl.* 3) from a drawing

made by Father DON ESTEVAN ROXAS Y MELO. The drawing is an excellent likeness of our Californian *Pelagophycus giganteus* Aresch., and will be discussed later. LEGENTIL consulted M. GUETTARD of the Royal Academy in regard to the nature of this plant and obtained the following opinion (*l. c.*):

Cette plante . . . est une espèce de celles qu'on appelle en France du nom de *varech*, goémon, et par les Botanistes de celui de *fucus*: cette espèce est singulière, en ce que le haut de la tige est terminé par un tubercule ou une vessie, dont les branches partent, et, en ce qu'il paroît, que les pedicules des feuilles sortent d'un même côté. Il me semble qu'elle n'a pas encore été gravée; je ne l'ai pas reconnu parmi celles dont il est parlé dans l'ouvrage de LINNÉ, intitulé *Espèces des Plantes*; elle n'est pas non plus dans l'ouvrage de SAMUEL GOTTLIEB GMELIN, qui en a fait graver un grand nombre d'espèces; on le voit point parmi les plantes de Mexique gravées dans l'ouvrage de HERNANDÉS sur ce pays; il n'est pas plus fait mention dans *l'Histoire des Barbades* par HUGUES, ni dans la *Collection des Plantes* de MORISON. Il me paroît que cette plante est nouvellement découvert par les Européens, et qu'il est bon d'en donner une figure gravée.

GUETTARD also supplied a Latin diagnosis, as follows: "Fucus ramis ex tuberculo rotundo exientibus, foliis planis, profunde crenatis, pediculatis, pediculis uno versu dispositis."

There has been some discussion as to the nature of *Porra* and other floating seaweeds of the western coasts of the Americas, and the best résumé thus far given is that of RUPRECHT (*l. c.*) who, although he had not seen the plate of LEGENTIL, came to the conclusion that it must be a species of *Nereocystis*, noting, however, the discrepancies between the descriptions and this *N. Luetkeana*, the only species known to him. A statement to the same effect is to be found in POSTELS and RUPRECHT's *Illustrationes Algarum* (p. 1), with the reference, however, to their species—*N. Luetkeana*—which is probably the *Porra* of some of the Spanish writers. There is also a *Porra* of the South American coasts, for RUPRECHT says (*l. c.* 22) that BORY identified the *Porra* with *Macrocystis*, and that the *Laminaria porroidea* of LAMOUREUX, as represented by the type specimen, is *Durvillaea utilis*. Again, MAURELLE, according to RUPRECHT, speaks of floating seaweeds found in lat. 38° 14' N. of two sorts: *Cabeza de Naranja*, or sea oranges, and *Zacate del mare*. The former are likely to be *Nereocystis Luetkeana*, while the latter, RUPRECHT argues with seeming probability, may be *Macrocystis*. I find on p. 98 of

Vol. I, of the English translation of LAPEROUSE's *Voyage round the world* (London, 1799), MAURELLE's observation that in lat. 47° 40' N. "they observed that the sea was colored as in soundings, and they saw numbers of fish, reeds twenty feet long, and a species of seaweed with a head resembling an orange." In spite of the suggestion that this may have been the *Alcyonium aurantium* Pallas, it seems most probable that it was *N. Luetkeana*. Later in the same volume, LA PEROUSE speaks of the same plant as follows: "As we advanced to the north and approached America, we observed seaweeds of a species entirely new to us. A ball of the size of an orange terminated a stalk forty or fifty feet long, resembling an onion run to seed, but much superior in size." This was in the latitude of Mt. St. Elias on the Alaskan coast, where floating *N. Luetkeana* is common.

Following the suggestion derived from RUPRECHT's account just alluded to, I have been able to find, by the help of Librarian F. J. TAGGART, a copy of the rare first edition (1780?) of MAURELLE's *Journal of a voyage in 1775 to explore the coast of America, northward of California* (reprinted in 1781 in PARRINGTON's *Miscellanies*), in the Bancroft Library of the University of California. MAURELLE's observations on the floating seaweeds, as there set forth, are as follows (p. 12):

June 1, 1775. On the same day we observed some seaweeds, the top of which much resembled an orange (*una naranja*), from the upper part of which hung large and broad leaves. At the extremity of this plant is a very long tube, which fixes it to the rocks on the coast until it is loosened by the sea, when it often floats to the distance of 100 leagues. We named this plant the "orange head." The next day we saw another plant with long and narrow leaves like a ribband, which is called *Zacate del Mar*; we also saw many sea-wolves, duck, and fish.

This observation was made when they were apparently well north of Point Conception and the "orange heads" were probably *Nereocystis Luetkeana*. Again he says (p. 25): "We observed that the sea was colored as in soundings; many fish, reeds 20 feet long, and the 'orange heads' likewise appeared." This was on July 9, apparently in the neighborhood of the Straits of Juan de Fuca. He goes on to say (p. 34): "On the 13th of July, we perceived ourselves to be in soundings from the color of the sea; at the same time appeared 'orange heads,' many flags," etc. At this time they were apparently in lat. 55° or 56° N.

Later on, when giving instructions as to approaching the west coast of North America from the Pacific Ocean, he says (p. 56):

When the coast is 80 or 90 leagues to the E., those sea-plants appear which I have before called "orange heads;" but I must now add, that from the state of them as they float, one may sometimes infer that the land is not so far distant. Its figure much resembles the fistular stalk of garlick; and from the top of its head hang some very long leaves, by which the plant is fixed to the rocks. Now if these leaves are tolerably perfect, they afford a strong presumption that they have not floated far from the coast. On the contrary, those which have been wafted to a considerable distance have generally lost this head, and the stalk becomes more rough, when you may suppose that you are 50 leagues from land. [He further says (p. 57)] When you are 30 or 40 leagues from the coast, . . . you will perceive birds, . . . together with the plant *Zacate del Mar* before mentioned, which has long and narrow leaves.

It is very evident that both species of the west-coast kelp with the large bulbs were known to the navigators, and it is of interest that the southern species *Nereocystis gigantea* Aresch. or *Pelagophycus giganteus* Aresch. was known so long before it was generally recognized by botanists. The description of GUETTARD, furnished to LEGENTIL, is reasonably explicit, but, when taken into account in connection with the plate referred to above, leaves no doubt as to the identity of the plant with that of ARESCHOUG. The first botanical description, however, was given by LEMAN (Dict. des sciences naturelles 25:189. Paris. 1822) under the article Laminaria. It reads as follows:

Laminaria porra nob. Stipe très-long, terminé par un renflement fusiforme, portant une grosse vessie sphérique, couronnée de frondes lanceolées, très-élongées et profondément dentées. Cette espèce a été observée dans le mer du Sud par LEGENTIL. Les marins espagnols la nomment *porra*. Elle se fait remarquer par sa longueur qui excède de quarante brasées ou de deux cent pieds. (Voyez LeGentil, Voyage Ind., p. 2. pl. 3.)

From this it becomes evident that the earliest specific name for the southern species is *Porra*.

ARESCHOUG first referred the southern or elk-kelp to the genus *Nereocystis*, but later created the genus *Pelagophycus* for its reception. The close resemblance between it and *Nereocystis*, however, has led most writers to retain both in the same genus. This was my own opinion in the paper entitled "The elk-kelp" (*Erythea* 4:179-184. pl. 7. 1896), but at the same time I called attention (*l. c.* 184) to the unequal splitting and the consequent close relation to *Macrocystis*.

SKOTTSBERG has given a most careful and valuable discussion of the relationships of the *Lessonia* group in the Phaeophyceae of his *Sub-antarktischen und antarktischen Meeresalgen* (Wiss. Ergebn. d. Schwedischen Sudpolar-Exp. 4:Lief. 6. 1907) and takes up this matter in that connection. His decision is to retain the species in *Nereocystis* (*l. c.* 139). He seems to incline toward the view that the splitting in *Nereocystis* is also unilateral. With this view, as indicated above, I cannot find myself in agreement. I have examined many, both older and younger, *Nereocystis Luetkeana*, with the result that I find the splitting to proceed fairly uniformly dichotomously as noted above. In *Pelagophycus*, on the contrary, the splitting is decidedly unilateral and like that of *Macrocystis*. A young plant, with characteristic adult form though not of adult dimensions, is represented in the photograph reproduced in connection with my paper. SKOTTSBERG has remarked that there are five leaves on one branch and six on the other. There were six on each, but on one only the petiole remains to show its position. In the specimen figured, the branching has been absolutely unilateral after the first splitting, as is shown by the fact that the leaves are single. In many specimens, however, some of the lower leaves divide a second time, as happens constantly in young specimens of *Macrocystis*, but not more than one or two usually do this. In this, as in other characters, this plant is intermediate between *Nereocystis* and *Macrocystis*. From all the evidence it seems to me best to keep the genus *Pelagophycus*, and to associate it with the *Macrocystaceae* under the tribe of the *Lessoniidae*.

As has been shown above, LEMAN's name of *Laminaria Porra* is the earliest binomial, which necessitates the new combination:

***Pelagophycus Porra*, comb. nov.**

Laminaria Porra Leman. Dict. Sci. Nat. 25:189. 1822.

Nereocystis gigantea Aresch. Bot. Notiser 1876: 71.

Pelagophycus giganteus Aresch. Bot. Notiser 1881: 49.

I desire to thank Mr. F. S. COLLINS of Malden, Mass., for transcripts of the reference of LEMAN and also that of LEGENTIL to *Porra*. To F. J. TAGGART, librarian of the Bancroft Library of the University of California, I am indebted for assistance in obtaining access to the works of MAURELLE, ANSON, and LAPEROUSE.